Injection-molding method

The invention relates to an injection-molding method in which plastic material under pressure is injected from an antechamber which can be shut off, into a mould cavity after opening of a shut-off means, and fills the mould cavity under pressure.

The operation of injecting the plastic material is usually effected by means of the screw which serves to plasticise the plastic material and which acts as a piston in the injection operation. There have however also been many proposals for passing the plasticised plastic material into a separate antechamber from which it is expelled by a piston which is independent of the plasticising screw.

Particularly in the production of small and thin-walled components, it is essential for the injection operation to be terminated rapidly as otherwise partial hardening of the plastic material already occurs in the cooled mould, during the injection procedure. In order to achieve high injection speeds, hitherto the advance speed of the screw or a separate injection piston which is possibly provided has been increased more and more. The invention is based on the thought that further development along those lines is not meaningful as, at high screw advance speeds. the molten material in the antechamber is primarily compacted, whereas that achieves little in terms of filling the mould cavity.

Therefore the object of the invention is to rapidly fill the mould cavity, particularly when injection-molding thin and small moldings, in which respect the speed of the injection piston is to play no part or only a subordinate part.

In accordance with the invention that is achieved in that the volume of the antechamber and the pressure prevailing therein, at the opening of the shut-off means, are of values, at the existence of which at least half of the pressure achieved in the mould cavity in the method occurs even if the volume of the antechamber is kept constant during the injection operation.

Insofar as hitherto a pressure which is comparable to the pressure in the mould interior has already been built up upstream of the shut-off means, prior to opening of the shut-off means, the only result of that was that the mould was initially partially filled by expansion of the plastic material in the antechamber until after some delay the action of the screw advance movement came into effect. In contrast, the invention is based on the notion that the entire mould cavity is filled merely by expansion of the supply of plastic material which has accumulated in the antechamber and which is under pressure. If in that respect a movement of the screw or other injection piston takes place intentionally or unintentionally, that only results in a modification of the adiabatic expansion method which in itself governs the filling of the mould. In practical terms that means that the pressure in the antechamber, which conventionally does not exceed 800 bars, is typically increased to over 1500 bars when carrying the invention into effect, and in particular that the volume of the antechamber is not reduced to a very substantial extent, as is usual, in the injection operation, but is entirely or predominantly maintained.

Details of the invention are described hereinafter with reference to the drawing showing a view in diagrammatic cross-section of an apparatus which is conventional in itself, for carrying the method into effect.

The method according to the invention can be carried into effect on any conventional injection-molding apparatus insofar as the feed flow to the mould cavity is controllable by a shut-off means. Therefore only the parts of an injection-molding apparatus which are essential to the method of the invention are described and illustrated here.

In the illustrated apparatus thermoplastic material is plasticised in the cylinder 8 by a screw 5 and passes into the antechamber 1. The antechamber extends through the bores 13 almost to the mould 7. Its front opening 14 is closable towards the mould 7 by means of a shut-off means 2, whereas a back-flow of the plastic material out of the antechamber 1 is prevented by a back-flow closure means 6 at the tip of the screw 5.

An essential functional part of the shut-off means 2 is in per se known manner a closure needle 9 which, under the pressure of the plastic material in the antechamber 1, has a tendency to move towards the right in the drawing. The

needle 9 is acted upon in the closure direction by a lever 11 which is pivotable about the pin 10 and which is subjected to the action of a controllable hydraulic unit 12.

It is essential for the invention that a substantially higher pressure is built up in the plastic material disposed in front of the shut-off means 2, than was hitherto usual, and that filling of the mould cavity 3 and the gate region 4 in front thereof, is effected by expansion of the plastic material in the antechamber 1. That does not exclude a movement of the screw 5 for increasing or reducing the pressure in the mould cavity 3 also being effected, to influence the pressure pattern in the mould cavity 3, after opening of the shut-off means 2. Opening of the shut-off means 2 can also be effected in a controlled manner in order to modify the pressure pattern in the mould cavity 3 which is determined primarily by the adiabatic relief of pressure of the plastic material in the antechamber 1.

In order to be able to suitably determine pressure and volume in the antechamber 1 for a given mould cavity 3, desirably firstly a volume which substantially exceeds the volume of the mould cavity 3 is selected for the antechamber 1. Then the desired pressure in the mould cavity 3 is selected. The pressure in the antechamber 1 which leads to that result can be ascertained in a simple series of tests. With knowledge of the state equation of the plastic material used, it is also readily possible to calculate that pressure. This will be subsequently demonstrated by means of an embodiment.

Example:

Material used: Polystyrene 143 E

Density at ambient temperature: 1.047 g/cm^3

Volume of the antechamber 1 in front of the shut-off means 2: 45.6 cm^3

Volume behind the shut-off means 2: 1.37 cm^3, of which 1 cm^3 actual mould cavity 3

The plastic material is under a pressure of 2000 bars, and its temperature is around 30° above the desired operating temperature of 220°C.

The shut-off means 2 is now opened, whereby the plastic material expands to the entire available volume, that is to say into the region 4 of the gate and into the mould cavity 3. Due to that adiabatic expansion, cooling by 30°C takes place and there is a pressure drop to the desired final range of 500 bars. That pressure is

generally easily sufficient for production of the desired product, but it can be increased by displacement of the screw 5, subsequently to opening of the shut-off means 2, or reduced (by displacement towards the left in the drawing).

It has been found that the mass enclosed in the antechamber 1 may differ from the theoretical value due to differences in the function of the back-flow closure means. This problem can be overcome by monitoring the pressure in the antechamber 1 as a function of screw position. If, for instance, the mass of plastic material in the antechamber is smaller than the ideal value, a certain pressure will be reached at a more forward position of the screw than in the ideal case. In such a case, the target value of the pressure is increased following a recalculation using the pVT diagram of the material in question.

It has also been found that the quality of the finished product is more uniform if there is a certain delay (preferably of one or two seconds) between the reaching of maximum pressure inside of the antechamber 1 and the opening of the shut-off means 2.